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A REVIEW OF LITERATURE ON *TARAXACUM KOK-SAGHYZ* ROD[1]

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INTRODUCTION

The recent rubber shortage in North America has induced considerable interest in every species of plant that might possibly serve as a source of natural rubber. Martin (120) has recently given a brief description of a number of such plants.

The Russian conclusion, that for cultivation outside the tropics kok-saghyz is one of the most promising, has led to the importation of this species into America, and for the last two and a half years it has been the subject of investigations in the United States and Canada.

This period of study is as yet too short to have resulted in many English publications, and the bulk of literature on kok-saghyz remains in Russian. Unfortunately this renders it almost inaccessible to the majority of English-speaking workers. To overcome this situation the National Research Council of Canada undertook a survey of the Russian literature on rubber-bearing plants in general and on kok-saghyz in particular. The survey has been carried out by the present author and this review is one of its results.

Owing to the scattered distribution of Russian publications it would be impossible to bring together just now the entire literature on kok-saghyz. Accordingly the scope of this review has been restricted to a survey of those papers that are to be found in certain American and Canadian Libraries and hence are most readily available to the North American investigator.

DISCOVERY AND BIOLOGY OF KOK-SAGHYZ

It was not until 1926 that a campaign was begun in the Russian press, urging the necessity of re-examination of the Russian native

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flora for new rubber-bearing plants which were growing under the climatic conditions of the U.S.S.R. (35). In 1928 a species of *Chondrilla* on the shores of the Caspian Sea was the first native rubber-bearing plant to be found. In a search for more extensive wild stands of it, a second native rubber-bearing plant—tau-saghyz—a species of *Scorzonera,* was discovered in 1929. Analysis of its dried roots revealed that they contained close to 40% of rubber. From these two examples it became clear that the Russian native flora contained some plants with considerable rubber in them, and that such plants were not known to Russian botanists. Early in 1931 it was decided to re-examine the Russian native flora, and a period of two years was given for this purpose. The actual execution of this re-examination was entrusted to Bosse and Prilutskaia, whose paper (35) represents their report.

In 1931 an expedition sent to Kazakhstan and headed by L. E. Rodin returned in the fall with the roots of a native plant called "kok-saghyz". In local language kok-saghyz meant "green chew", since the plant is used by the local population as a masticatory. The roots were planted in a greenhouse of the Botanical Institute in Leningrad where they produced leaves and flowers, and it was from these specimens that the first botanical description was given under the name of *Taraxacum kok-saghyz* Rodin (118).

In 1932 a special expedition was sent to Kazakhstan to study kok-saghyz in its natural habitat and to report on the feasibility of its introduction into cultivation. The report subsequently was given by S. Lipschitz (109). According to it, the native habitat of kok-saghyz is in the valleys of the Tien Shan mountains, between 79° and 80°30′ east longitude, 42°20′ and 43°20′ north latitude. The elevation of this region varies between 1,800 and 2,000 meters above sea level and its climate is continental. While the soil conditions in these valleys vary considerably, kok-saghyz prefers to grow on soils which have from average to low salt content, large amounts of humus and a high degree of moisture. Kok-saghyz plants often invade cultivated fields where they thrive and grow luxuriantly.

This expedition reported kok-saghyz to be a very promising plant for rubber production, and recommended its introduction into cultivation. It was also suggested that until cultivated plantations of it become established, its wild stands should be looked upon as

temporary sources of seeds. Collection of seeds from these wild stands has been described by two authors (37, 89). According to the first, the total area of kok-saghyz stands is close to 2,000 hectares (hectare = 2.47 acres). These are distributed in the three valleys of the Tien Shan mountains and are scattered among the local meadows in areas of 0.5 to 175 hectares. According to the second author, in order to insure that collected kok-saghyz seeds were not contaminated by those of other dandelions, they were accepted from the local population only during the season when seeds were produced on the kok-saghyz plants. As a further precaution, only whole heads of plants, never seeds alone, were accepted. The presence of "horns" on the involucral bracts of kok-saghyz heads was the main characteristic used for the separation of these heads from those of other dandelions. It was later found, however, that in spite of such precautions, the seed material collected from the wild stands contained some admixture of other dandelions. According to Lipschitz (109), in 1932 this admixture was about 5.8%. Koroleva (94), however, reported that in one case seeds collected from a wild stand produced more than 50% of other dandelions than kok-saghyz. This worker described nine different species of *Taraxacum* which may be found growing together with kok-saghyz, and she gave the characteristics for their separation.

Taraxacum kok-saghyz Rod. is a perennial dandelion, and its general appearance is somewhat similar to that of the common dandelion. In its native habitat there have been found specimens with roots probably seven years old (109), while plants growing on a plantation for four years were also reported (94). Commercially, kok-saghyz is grown either as an annual or a biennial. It has either a tap or a branched root, and in its native habitat the average air-dry weight of a root is 0.8 to 1 gram with the rubber in it varying from 2.98% to 27.89% (109). The upper end of the root, known as the crown, bears either one or several rosettes of leaves. Each rosette has a diameter of 15 to 40 cm. and consists of 20 to 50 leaves which are more or less pressed against the ground. Leaves may vary in shape from lanceolate and obovate with practically entire margin, to pinnately lobed and even divided.

Later in the season each plant may produce up to 96 peduncles, each of which bears a head. Each head contains 25 to 50 flowers, protected by the involucral bracts two or three layers thick. Fruits

are small achenes, and about 3,000 of them weigh one gram. As is true of other dandelions, they are disseminated by wind.

The main distinguishing characteristics of kok-saghyz which enable one to separate it from other dandelions are (94, 109):

(*a*) Threads of rubber between the two halves of a severed air-dry root are visible.

(*b*) Leaves are fleshy, without small teeth on their margins, and are bluish with a glossy surface. The wide midrib is of light colour, while the side veins are poorly developed.

(*c*) Involucral bracts have small "horns" at their ends.

One of the striking characteristics of kok-saghyz is considerable polymorphism of its leaves. In the same population one can find specimens with simple, pinnately lobed and pinnately divided leaves. It has been thought by many students that such polymorphism indicates the existence of genetically different forms. Lipschitz (109), for instance, tried to determine whether there was any difference in the germination of seeds collected from plants with simple and with lobed leaves. He found that the percentage of germination of seeds from these two forms was practically the same. As early as 1934 it was reported (100) that the largest roots are possessed by plants with pinnately lobed and not with simple leaves. On the strength of this observation it was suggested to select kok-saghyz plants with pinnately lobed leaves.

Lebedeva (104) investigated the effects of external conditions and of the ontogenetic stage of the plant itself on the morphological characteristics of its leaves. She reported that with advanced ontogeny and with favorable external conditions there occurs on the same plant an increase in the percentage of its lobed and a decrease of simple leaves. That external conditions may influence the forms of kok-saghyz leaves has also been reported by others (50, 134).

In the first year of growth kok-saghyz plants may begin to flower 60 to 70 days from the time of sowing, and the period of flowering may extend until late in autumn. In the second year of growth flowering is much heavier, and on such a plantation it lasts one and a half to two months. In a kok-saghyz head the florets are arranged in a series of concentric circles, and various stages in the opening of a head have been described by several workers (94, 137, 139).

Sexual reproduction is normal (158). Cross-pollination is the

usual method, but self-pollination may occur occasionally. After pollination a pollen grain begins to germinate on the stigma within five minutes, and a pollen tube reaches the embryo sac within 15 to 20 minutes. Under favorable conditions fertilization has been observed to take place 40 minutes after pollination, and six days later the embryo was fully developed. The somatic number of chromosomes is 16, while the sperm and egg cells have eight. Pollination in kok-saghyz has been studied also by Ghilarov (60). These conclusions on the normal sexual reproduction (158) have been confirmed (209, 221).

In the first year of growth only a small percentage of kok-saghyz plants produce flowers. A comparison between flowering and non-flowering plants in the first year of their growth revealed that at the end of the growing season flowering plants attained a greater fresh weight than the non-flowering (124). While the percentage of rubber in such flowering plants was somewhat lower, due to their greater weight, the absolute amount of rubber in them was higher. Similar observations as to the difference between flowering and non-flowering specimens have been made on plants grown from stratified seeds (3). On the other hand, one can also find in the literature statements that from the commercial point of view plants not flowering the first year are more desirable (88, 95, 99).

Borthwick, Parker and Scully (32) reported that none of their photoperiods varying from 8 to 18 hours completely inhibited development of flower primordia on kok-saghyz into mature flowers, though on a 12-hour or longer photoperiod they flowered somewhat more freely. Siniavskii (191) reported the existence of one form which in the first year flowered only after treatment with low temperature, while the second form did not require low temperature treatment but flowered only on a long day.

Between the appearance of flower buds and production of seeds from them there is a period of about 16 to 18 days. Freshly gathered seeds usually have a low percentage of germination, but the percentage increases during subsequent storage. Thus Poptsov (167) cites a number of examples wherein the percentage of germination of seeds gathered early in July was between 20 and 25, while 12 days later it was doubled. According to the same author, the length of this period of post-harvest ripening varies from year to year and is affected by the conditions of storage. In order to elim-

inate such post-harvest seed dormancy, this author recommends stratification, and he carried out a number of experiments (166) to determine the best external conditions for such treatment.

The stratification technique recommended for general practice has been described by a number of authors (1, 10, 197, 212). Following their stratification and in order to facilitate subsequent sowing, seeds should be slightly dried until they run. It was reported, however, that when stratified seeds are dried even only for two to three hours, the percentage of their subsequent germination decreases (166). Levitt and Hamm (108) reported an increase in germination when the seeds were permitted to absorb water in amounts insufficient to induce germination, and then were dried.

Aksel'rod (3) found that treatment of kok-saghyz seeds before sowing not only resulted in more uniform germination but also had marked effects on the subsequent development of plants produced from such seeds. Such plants flowered ten to twelve days earlier, and a higher percentage of them flowered the first year. From his data this worker also concluded that seed treatment between 0° and +2° C. for 14 days is just as effective as for 25 days.

Sirotkin (193) has confirmed the earlier flowering of plants grown from seeds pre-treated at 0° C. This worker has also suggested that on the basis of their reaction toward low temperature treatment there are two different forms or races of kok-saghyz. One form is similar to a fall wheat which requires a considerable period of low temperature treatment before it is induced to produce flowers. The other form is like spring wheat in that it requires only a short low-temperature treatment. The beneficial effects of low-temperature treatment on subsequent flowering have also been reported by other workers (32, 99).

ANATOMY

Roots. Blokhintseva (21) studied changes in the anatomy of a kok-saghyz plant during the first year of its growth. A root of a one- or two-day old seedling was found to have a primary cortex six to eight cells thick, protected by epidermis and a well differentiated endodermis. The root is usually diarch, and it contains two groups of primary latex tubes. In a three-weeks old root the epidermal layer loses its root hairs and becomes cutinized. Vascular cambium actively produces secondary tissues with considerable excess of

phloem over xylem, and by that time primary cortex has been pushed to the periphery and is crushed. Secondary phloem has groups of secondary latex tubes arranged in two or three concentric circles, each group containing three or four latex tubes.

When flower buds appear the primary cortex has already been sloughed off and the secondary phloem is protected on the outside by a cork layer several cells thick. Secondary phloem contains seven or eight concentric rings of latex tubes arranged in groups, each group consisting of four to six latex tubes. At the time of fruit formation, secondary phloem contains nine to eleven concentric rings of latex tubes.

While all Russian investigators say that sieve tubes of kok-saghyz are very small and difficult to find, Artschwager and McGuire (19) investigated them more thoroughly. These two workers state that "although the sieve tubes of kok-saghyz are relatively narrow compared with those of members of the Cucurbitaceae, they form in their entirety a well developed system, capable of expediting translocation and making rapid growth possible".

In the second year of its growth, as is characteristic of all perennial dandelions (172), kok-saghyz sloughs off all secondary phloem produced the previous year. This process of sloughing off was first described by Rudenskaia (180). At the beginning of the second year of growth a cork cambial layer appears on the boundary between the region of the last year phloem and the new one. This cambium produces cork which separates from the rest of the root all the phloem produced the previous year. As a consequence all the separated cells die and are pushed to the outside.

These crushed tissues pushed to the outside contain all the rubber produced the previous year, and they form a compressed layer which in Russian literature is called a "glove". A series of diagrams to show the sloughing off of such a "glove" is given by several authors (125, 191). This "glove" is sloughed off the root shortly after the peak of seed production has been reached. In its native habitat a kok-saghyz root does not shed its "glove" but merely pushes it to its periphery. Thus Lipschitz (109) described an old root which had on its periphery five such "gloves". While some (180) think that a "glove" is sloughed off the root as a result of centrifugal pressure exerted by newly formed cells, others (122, 123, 127) believe that a "glove" is broken down by micro-organisms

in the soil. In support of their belief they cite the work of Kalinenko (75) who reported on the destruction of rubber by several micro-organisms.

Besides kok-saghyz plants of the usual anatomical characteristics described above, one occasionally finds specimens with a number of abnormalities. Thus roots with triarch instead of diarch structure of their stele have been reported (19). On a cross section of a root, xylem may not appear as a ring but in an irregular form (172), or even be broken into a number of parts (109). Roots have been reported (52), which, in addition to the usual cambial ring in the center, also had a number of additional small rings scattered irregularly throughout the region of the secondary phloem. It was suggested that it is this last "abnormal" structure which is the most desirable one from the agricultural point of view. In such a root addition of new cells and of new latex tubes can take place not as a result of the activity of only one, but of several cambial rings.

Latex tubes system. No latex tubes are found in any part of an ungerminated seed (21, 186). They begin to differentiate as soon as water is taken by a seed during germination. The first or primary latex tubes appear in the pericycle in close association with the phloem cells (19, 186), while the secondary latex tubes are differentiated in close proximity to the cambium (181). Latex tubes are produced by fusion of several cells in tandem at their cross walls (19, 21, 186) and by subsequent differentiation of the resultant fused cells. They are living structures containing cytoplasm and nuclei, the number and the shape of which vary according to age (24, 26).

Latex tubes of the same circle anastomose freely, though there is no connection between the tubes of different circles (19, 181, 186). It has been stated (152) that all the latex tubes of a kok-saghyz plant form a single continuous system, with the tubes of the leaves joining in the crown region on those of the roots.

It has been reported (151, 181) that practically all latex tubes of a mature root are formed and reach their maximum diameter before the peak of flowering is reached. In other words, at this stage the rubber-holding system of a kok-saghyz plant has attained its maturity. On the other hand, the greatest increase in diameter of a root as a whole occurs later, after the peak of flowering, and such

an increase is caused mainly by enlargement of the phloem parenchyma cells. As a consequence of this early development of its latex tube system and later growth of the root as a whole, there occurs after flowering a decrease in the number of latex tubes per unit area of the root. Since at the same time there also is not a decrease but an increase in the percentage of rubber in the whole root, it has been concluded that a considerable simultaneous increase in the concentration of rubber within the latex tubes must take place (151, 181).

Filippov (52) tried to correlate the diameter of a root with the percentage of rubber in it. He found that the percentage was inversely proportional to the diameter, and he explained this as being due to the lower number of latex tubes per unit of root area observed in roots of larger size.

Others (172) have described a definite gradient both in the number and in the average diameters of latex tubes in a kok-saghyz root. The smallest diameter and the smallest number of tubes per millimeter of root section are near the crown. Both these values increase toward the apex, reaching a peak 17.5 to 22.5 cm. from the crown, and then decline again. Such a gradient in diameter and number of latex tubes along the root is correlated with a similar gradient in percentage of rubber in both one- and two-year old roots, as reported in this and other papers (52, 169, 191).

PHYSIOLOGY AND BIOCHEMISTRY

Nitrogen and carbohydrate metabolism. Changes during the ontogeny of kok-saghyz plants in the first year of their growth were studied by Nichiporovich and Burovaya (150, 151). They found that an increase in dry weight continues until the very end of the growing season. In the period of growth before the peak of flowering has been reached, the plants produce mainly leaves. From the peak of flowering until the end of the growing season the bulk of the new dry matter is deposited in the roots.

In the period of their intensive growth, the leaves contain the bulk of the total nitrogen of the plant. From the peak of flowering until the end of the growing season the capacity of the leaves to synthesize proteins declines, and proteins already present in the leaves are partly hydrolyzed. Some of the products of such hydrolysis accumulate in the leaves, but a larger proportion is trans-

located to the roots. As a consequence, the total nitrogen content of roots by the end of the growing season is higher than that of leaves. Similar observations on the nitrogen metabolism in one- (164, 185) and two-year (105) old plants were reported by other workers.

Until flowering is reached the total sugar content of leaves is relatively low, with the reducing sugars either equal to or slightly in excess of the disaccharides. After flowering the total sugar content is increased and remains at a high level until the end of the growing season.

Changes in the water-soluble polysaccharide of kok-saghyz roots, which all Russian workers describe as inulin, have received considerable attention. The reducing sugar content of mature roots, as compared with that of inulin, has been found to be low (79, 185). The absolute amounts of inulin in one-year old roots were found to increase continually throughout the whole growing season, with the bulk of it being formed after flowering (79, 150, 151). On the other hand, the highest percentage of inulin both for one- (79, 150, 151) and for two-year old roots (105) has been reported at the time of flowering, and it declines somewhat towards the end of the growing season. This is different from what is observed in the ordinary dandelion, in which the highest percentage of inulin has been reported (115) to occur late in the fall.

Using microchemical tests, Blokhintseva (21) has tried to localize reducing sugars, inulin and rubber in one-year old kok-saghyz plants which were in various stages of their ontogeny. In leaves this worker found reducing sugars only after flower bud formation. In roots sugars and inulin were observed for the first time at the time of flower bud formation. At this stage both sugars and inulin were present inside the root parenchyma cells. Sugars were particularly abundant around the latex tubes, while inulin was spread throughout the whole phloem. At flowering, large amounts of sugars appeared inside the latex tubes, while inulin became localized in the form of rings around the latex tubes.

Using similar methods of analysis, this worker (25) found that by the middle of October kok-saghyz roots contained both inulin and reducing sugars inside the parenchyma cells of both phloem and zylem. After two months of storage there was practically complete disappearance of inulin and considerable accumulation of both mono- and disaccharides.

Seasonal changes in rubber and resins. That the amount of rubber in a kok-saghyz root depends on the ontogenetic stage of the plant has been reported by a number of workers. According to Minbaev (135), in the first year of growth the percentage continuously increases until late in the fall, after which date there is a slight decrease. The rubber content of roots in the second year of growth, as a rule, is higher than in the first year. In the third year, the percentage goes down, which this worker attributes to age.

Mashtakov (123) followed qualitative and quantitative changes both in the rubber and in the resins of one- and two-year old roots in various stages of development. This worker reported continuous accumulation of rubber and decrease in resin content during the whole period of vegetative growth in the first year. The same was true for the rubber and resins produced in the the new tissues formed in the second year of growth. On the other hand, in the second year of growth the absolute amount of rubber in the "glove" remained fairly constant until the peak of seed formation had been reached, when it declined as a result of the sloughing-off process. The percentage of rubber in the "glove" had been, however, continuously increasing until the "glove" was sloughed off. This increase is attributed to the loss of dry matter in the "glove" itself (123, 125). The sum of changes in the new tissues produced in the second year of growth together with changes taking place in the "glove" determine the seasonal variations in the rubber content of the whole kok-saghyz root during the second year of its growth. From early spring until the peak of seed production there is a continuous increase of both absolute and relative amounts of rubber in a two-year old root. When the "glove" has been shed, the rubber content of such a root goes temporarily down, but it begins to increase again and continues to do so until the end of the growing season. According to this worker (121, 123, 125), the viscosity, molecular weight and degree of polymerization of rubber continuously increase during the normal life of both one- and two-year old roots. Depolymerization and quantitative decrease in the amount of rubber takes place only in the dying tissues, or in a "glove", and is due to the action of micro-organisms. With progress of the season both the absolute and relative amounts of resins decrease. At the same time their saponification, acid and ether numbers go up, iodine number remains fairly constant, and the index of refraction is decreased.

Blokhintseva (22) determined the refraction index of the rubber granules inside kok-saghyz latex tubes. She found that in younger plants and in those latex tubes which were closer to the cambium and consequently younger, the refraction index was higher. She suggested that a higher index is due to an admixture of resins, which in the earlier stages of development are present in larger amounts.

Nichiporovich and Bourovaya (150, 151) observed the greatest accumulation of rubber in a kok-saghyz root during the second or maturation stage of development. They suggested that by promoting such maturation one can stimulate accumulation of rubber in its root. These two workers (151) also suggested that resins in kok-saghyz might be by-products of general growth processes, probably connected with synthesis of proteins. They base their suggestion on the observation that the ratio between the amounts of resins and proteins in the roots remains practically unchanged throughout the whole vegetative period.

Synthesis of rubber. Nichiporovich (149) cites several examples to indicate that in a number of rubber-bearing plants the capacity to synthesize rubber is far in excess of the actual amounts of rubber present in them. He concludes, therefore, that the external conditions which bring about an increase in the rubber content of a plant do not promote the actual synthesis of rubber itself but act by stimulating an increase in the size of the receptacles in which rubber is stored.

As to the place of rubber synthesis in a plant, there exist two different opinions. According to one, rubber is produced in the mesophyll of a leaf and is transported as such to other parts. The latex tubes system is, therefore, simply a transportation system. According to the second opinion, rubber is produced not in the mesophyll of a leaf but within the latex tubes, probably from some carbohydrates. The latex system functions, therefore, both as a means of rubber translocation and as the site of its synthesis.

Zelinsky and Rapoport (213) suggested that isoprene is a "product of assimilation of carbonic acid under the action of light and chlorophyll as starch and carbohydrates in general". A close relation between illumination and synthesis of rubber has been reported by several workers (132, 153). From their observations on the diurnal changes in the rubber content of tau-saghyz leaves,

it has been concluded that rubber is produced in the mesophyll of leaves under the action of light, and that from the assimilating cells it is moved to the latex tubes and transported further (85).

According to Nichiporovich (149), since rubber is a highly polymerized substance, we can expect, on theoretical grounds, that its predecessors of lower degree of polymerization might have physical characteristics quite different from those of the final product. From the observation that many rubber-bearing plants contain in their assimilating cells substances which give various reactions characteristic of rubber, this author concluded that the bulk of rubber in plants is produced in the mesophyll tissue of their leaves. He suggests that such rubber is of low degree of polymerization, is easily soluble and is transported to other parts of the plant where it is polymerized further into insoluble rubber. This author concedes, however, that some true synthesis of rubber may also occur in some non-assimilating cells.

In both the palisade and spongy tissues of kok-saghyz leaves one can find round, glittering drops of inclusions which in Russian literature are called "mesecret" (mesophyll secretion). In order to determine whether these mesecret drops contain rubber, Blokhintseva (23) investigated their composition in various stages of development. From the data obtained she concluded that mesecret drops in kok-saghyz leaves hardly contain rubber. In her later paper (24) this worker makes an even more emphatic statement that "synthesis of rubber in kok-saghyz is not connected directly on photosynthesis. Absence of rubber in the mesophyll secretion indicates, that synthesis of rubber does not take place in the assimilating tissues of the leaves".

According to Blokhintseva (24, 26), rubber in kok-saghyz is produced inside the living latex tubes. Since in comparison with that of a root the latex system of a leaf is developed to a considerably smaller extent, the bulk of rubber, according to her, is synthesized in the root. Having observed a protein covering on the outside of the granules of rubber, this worker thinks that rubber in kok-saghyz is formed in the cytoplasm as a result of the activity of plastids. The presence of protein covering on the granules of rubber is supported by Prokof'ev (173). Rubber granules in kok-saghyz are always spherical, and they increase in size with the progress of the season (224). Inside the old latex tubes, or under

pathological conditions (25), rubber granules coalesce and form rubber threads. In the first year of growth, such rubber threads appear for the first time after seed formation. Since no plasmolysis takes place in those latex tubes in which threads have appeared, Blokhintseva concluded that such latex tubes are dead and consequently have lost their capacity to synthesize more rubber. In support of her belief that rubber in kok-saghyz is formed not in the leaves in direct connection with photosynthesis but inside the latex tubes, this author also cites two other pieces of evidence: first—the appearance of rubber in a germinating seed, when cotyledons are still covered with the seed coat and before photosynthesis takes place (21); second—formation of rubber in seedlings which have germinated in darkness (24).

Prokof'ev (173, 231–233) also believes that rubber in kok-saghyz is produced in the latex system of its root and that this is done without any direct connection with photosynthesis. In support of his opinion he points out that rubber does not diffuse through the cell membrane and that once it has been formed in a cell it cannot leave it. Moreover, from the results of his own experiments with tau-saghyz, he doubts that latex tubes can function as a transportation system. He also quotes the experiments of Mazanko, in which tau-saghyz roots continued to synthesize rubber even after their leaves had been removed. Mashtakov (122) reported synthesis of rubber in kok-saghyz roots during their rest period, *i.e.*, when photosynthesis was not taking place. Neuman and Dobrovol'skaia (146) observed an increase in the rubber content of kok-saghyz roots during storage.

Physiological rôle of rubber. The question of synthesis of rubber in a plant is closely connected with that of its rôle. There is no uniformity of opinion on this subject, either. Some workers think that in a plant rubber serves some protective rôle; others look upon rubber as a reserve substance. Finally, a third group consider it to be a product of excretion.

According to Prokof'ev (173), rubber in kok-saghyz and a number of other plants cannot serve any protective rôle, as is indicated by the fact that numerous insects and cattle eat the plants. After an extensive survey of literature (174) Prokof'ev comes to the conclusion that rubber does not serve as a reserve substance either. Quoting from the experiments of Mazanko (126) on the

disappearance of rubber from the roots of tau-saghyz in starvation, Prokof'ev (174) concedes, however, that under some conditions rubber may disappear from plants. He makes, however, two qualifications: first, such disappearance occurs not under normal but extreme conditions of starvation; second, this disappearance may be only apparent, due to the change of an α-soluble rubber into an insoluble β-one (175). According to Prokof'ev (174), rubber is the end product of plant metabolism. That rubber is not an excretory product but a by-product of plant metabolism was concluded also by Pavlov (157).

According to Nichiporovich (149), the rôle of rubber in a plant may vary, depending on the degree of its polymerization, and rubber with low polymerization may serve as a reserve substance. In support of this opinion he quotes the results of experiments in which rubber disappeared on starvation of plants and reappeared either on illumination or on the injection of carbohydrates.

That rubber in a plant may be present in several forms whose rôles may also be different was suggested by Bosse (33, 34). According to this worker, the first step in the elucidation of the rôle of rubber in plants must be the working out of a better method of rubber analysis, which will permit one to differentiate between various forms of rubber in a plant.

Mineral nutrition. The effects of mineral nutrition on kok-saghyz, in general, and on the accumulation of rubber, in particular, have received considerable attention from a number of workers. Since kok-saghyz is grown as an annual for rubber and as a biennial for both seeds and rubber, it has been suggested that experiments on its mineral nutrition cover not one but two years of its life (211). The majority of experiments reported so far cover, however, only the first year of growth.

Nichiporovich and Burovaya (151) found that the ash content of kok-saghyz plants, particularly of its leaves, is very high. This observation indicates high demands for inorganic constituents. While at the beginning of the season leaves contain eight to ten times more nitrogen than roots, toward the end of the season the total amounts of nitrogen present in the roots and leaves are about equal. Leaves also contain about three times as much calcium and potash as do roots. On the other hand, the amount of phosphorus in roots is very high, being slightly higher than in leaves, even at

the beginning of the growing season. By the end of the season it becomes practically twice as high in roots as in leaves.

It has been reported by several workers (4, 76, 77, 78, 185) that in the earliest stages of kok-saghyz ontogeny, which corresponds to the stage in which a rosette of leaves is formed, there must be present fairly high amounts of N in the soil. That large amounts of N in this stage of plant development have a depressing effect has also been reported (39, 78, 80, 116). Increased amounts of N must be available to kok-saghyz during flowering and seed formation (4, 77). In the stages from completion of seed production until the end of the growing season, the amounts of N should be lowered again (82). Large amounts of it in this last stage of growth will stimulate production of leaves at the expense of roots (76, 77, 78). While some reports (116, 185) indicate that accumulation of rubber in kok-saghyz is more active on NO_3 than on NH_4, according to the more recent work this may not always be true. Thus it was reported (77, 82, 112) that roots had a higher percentage of rubber in them when the plants received N as NH_4 rather than as NO_3.

From the observation that phosphorus stimulates biological maturation of kok-saghyz, Nichiporovich and Burovaya (151) have recommended that increased amounts of it be given after the peak of seed production. This conclusion has been supported by other workers (4, 78). On the other hand, it has been pointed out (39, 78, 116, 130, 185) that a high level of phosphorus nutrition should also be present in the earliest stages of development.

It has been reported by several authors (116, 117, 145,) that addition of K decreases the rubber content of roots. On the other hand, Kalinkevich (77, 78) points out that this is true only when in the later stages of ontogeny the level of the N nutrition is too high. When this level is low, addition of K increases the longevity of the leaves and brings about an increase and not a decrease in the amount of rubber in the roots (77, 78, 185).

That kok-saghyz responds favorably to several trace elements (84), radio-active elements (42) and calcium (84, 117, 129) has been reported. The amounts of various trace elements in kok-saghyz have been determined (31).

Several workers have tried to determine the effects of mineral nutrition on plants, in general, and on kok-saghyz, in particular,

one is constantly finding emphasis laid on the two following points: first, that the needs of a plant for various elements is not constant throughout its whole ontogeny, but varies, depending on the stage in which the plant is (38, 39, 76, 77, 78, 80); second, that the after-effects of a shortage or an excess of an element early in ontogeny may have pronounced effects also in later stages of growth (77, 78, 80, 164).

Several workers have tried to determine the effects of mineral nutrition on the physiological and biochemical characteristics of kok-saghyz plants. Thus it has been reported (79) that an increase in the end content of the soil brings about an increase in the $\frac{\text{reducing sugars}}{\text{invert sugars}}$ ratio of leaves in any stage, while a higher K content increases the relative proportion of cane sugar (76).

In drawing conclusions from the results of analysis on the effects of various elements on the biochemical characteristics of a plant, one should remember, however, that the same element may have different effects, depending on the ontogenetic stage of the plant. Thus there is a statement that "increased amounts of N fertilizers bring about even a decrease in the amounts of carbohydrates" (145). On the other hand, Kalinkevich (80) has published data to indicate that in the early stages of ontogeny higher amounts of N fertilizers brought about an increase and in the later stages a decrease in the total sugar content of kok-saghyz leaves.

Water content of the soil. That kok-saghyz in its native habitat prefers a high percentage of water in the soil has been pointed out (109). It has been reported (103) that the higher the water content of the soil is, the greater the final dry weight of the plants, the higher their percentage of rubber and the shorter the time before appearance of flowers. The greatest need for water is in the first period of growth up to the time of flowering. Observations made by these two workers have been confirmed (214).

Summer dormancy. One of the biological characteristics of kok-saghyz is its temporary period of rest in the middle of summer in the second year of its growth. It was suggested (205) that a strong tendency towards a resting period occurs after flowering and formation of fruits. Since at this stage the synthetic activity of its leaves decline and there occurs an accumulation of various soluble substances which are at least partially translocated to the roots, one

expects theoretically to find at this stage of growth an increase in the osmotic pressure of the cell sap of both leaves and roots. Such an increase has been observed (205). It was also reported (205) that dusting plants with chalk or watering them slows down the rate of increase in their osmotic pressure and delays the onset of their period of rest. Removing flower buds from some two-year old plants and leaving them on others, Lebedeva (105) found that such treatment only delayed the onset of the period of rest but did not eliminate it completely.

On the other hand, it was suggested (147) that the summer rest of kok-saghyz is caused not so much by the fact that the plants have then reached a definite stage of their ontogeny but by unfavorable external conditions. In support of such an opinion these two workers (147) cite their experiments on both one- and two-year old plants which grew under favourable external conditions and did not enter rest periods, while comparable plants growing in the fields did. Since leaves of kok-saghyz are sensitive to high temperature and insolation, a decrease in these factors theoretically should also eliminate a rest period. They also cite experiments in which dusting or shading with cheese cloth either cut down the number of plants entering a rest period or completely eliminated it.

ANALYTICAL METHODS FOR DETERMINATION OF RUBBER

The method of analysis which has been very widely used by Russians in their work with rubber-bearing plants is that of bromination. This microscopic method was orginally a qualitative one (170), though later it was made quantitative (171). It has been used particularly in field work and where the facilities of the usual chemical laboratory were not available. Kostriukova (96) has modified the method for studying the rubber content of leaves. Blokhintseva (22) has combined this bromination method with that of Becke for the determination of the refractive index of solid substances. Ignat'ev (35) suggested cold extraction of air-dried plant tissues with chloroform. Such an extract can be prepared in the field and sent to a properly equipped laboratory to be analyzed for its rubber content. In order to follow the rate of rubber extraction from the roots in a factory, Izriumov (74) suggested a method for quick determination of rubber, using both a solvent for extraction of the rubber and a centrifuge to remove the non-soluble residue.

In selecting kok-saghyz roots with the highest rubber content it is necessary to analyze large numbers of plants in a short period of time. Several different methods have been suggested for this purpose. Stolbin (201) proposed a quick method based on the digestion of roots first in 3% NaOH, then in concentrated H_2SO_4, and finally determining gravimetrically the film of rubber so isolated. Koialovich (91) improved Stolbin's method by taking samples for analysis from a definite region of the root, by previous drying of the samples to eliminate loss of latex, and by eliminating digestion with concentrated H_2SO_4, which affects the rubber itself. Goriainov (66) suggested an electrometric method based on the determination of the E. M. F. in the living roots. A quick method, based on the appearance of rubber threads between the two ends of a broken air-dried root, has also been suggested (1, 197). This last method is recommended in mass selection of kok-saghyz roots according to their size.

CULTIVATION

From an examination of the various rubber-bearing plants which can be grown in the Soviet Union, various workers (7, 8, 43, 54, 183, 184) have concluded that kok-saghyz is at present the most promising plant. It greatly responds towards the improved conditions of cultivation and can stand a variety of climatic conditions. Potentialities of kok-saghyz cultivation seem to compare favorably with those of *Hevea* (192).

Numerous books and booklets (1, 10, 15, 55, 92, 98, 118, 128, 148, 168, 197), papers (6, 8, 138, 154, 183, 184, 200, 215) and pamphlets (40, 41, 113, 114, 199) supply instructions on the cultivation of kok-saghyz, and several authors (12, 20, 106, 131, 161) have described their experiences in growing the plants. Since cultivation in many respects is similar to that of sugar-beet, many practices used in the cultivation of the latter have been adopted for kok-saghyz without any modification (203).

Practically all authors emphasize the importance of choosing proper soil and proper predecessors (200). Kok-saghyz requires rich, not too heavy soil, and does best on peat and muck. For this reason White Russia, with a large percentage of its land under peat-bogs, has been considered an important potential region of U.S.S.R. for future cultivation of kok-saghyz (2, 14, 83, 128). Since the plant does not like an acid medium (117), such soils must be heavily limed (129).

Growing very slowly in the first three or four weeks of its life, kok-saghyz requires soil free from weeds. For the same reason it is recommended to weed its plantations and to cultivate between the rows at least four or five times during the growing season (13), and to dig out other species of dandelions at least twice. Minbaev (136) compares various characteristics of kok-saghyz with those of the common dandelion. According to his data, the common dandelion has a far greater vitality than kok-saghyz and on cultivated fields is a far stronger competitor of it than any other weed.

Having roots which penetrate into the soil to a great depth, kok-saghyz requires deep plowing. For spring sowing, plowing should be done in the fall, while for fall sowing it should be done four to six weeks before the sowing. It was reported that in the spring kok-saghyz seeds begin to germinate when the temperature reaches 5° to 10° C. (142), though for uniform and rapid germination they require temperatures between 25° and 30° C. (210). Since the usual temperature at the time of spring sowing is much lower than 25° C., dry seeds sown in the spring do not germinate uniformly. If, however, they are sown in the fall, remain in the ground during the whole winter and germinate only the following spring, then, provided other conditions are satisfactory, they germinate quite uniformly. For this reason sowing in the fall was recommended in the earlier instructions (16, 98, 107, 113). On the other hand, fall sowing has several drawbacks. Too early sowing in the fall results in the seeds germinating the same fall. As a consequence, a large proportion of young seedlings are killed during the winter, although mature roots can stand temperatures as low as −29° C. (48). Too late sowing in the fall precludes proper covering of seeds with soil, and this again cuts down the number of seeds germinating the next spring. Moreover, stratification of seeds suggested later resulted in their uniform germination even at the low spring temperatures. For these reasons spring sowing is recommended in later instructions (1, 10, 194, 197).

It was pointed out by Lissenko (110, 111) that cultivation of the soil immediately before sowing has been the main reason why spring sowings with stratified seeds have yielded poor results. He noted that such cultivation dries the upper layer of the soil in which small kok-saghyz seeds are deposited during sowing, and for

this reason the seeds can not germinate properly. The more recent views on how to carry out spring sowing of kok-saghyz have been given by Zasiadnikov (212). Since kok-saghyz seedlings are very weak, they break through the soil only with great difficulty. Sprinkling freshly sown rows with humus has been recommended to prevent formation of the soil crust and to insure more uniform appearance of the seedlings (163). It was suggested earlier (49) that if kok-saghyz seeds are incorporated into small clay balls and such balls are sown in the field, then the seedlings grow in small clusters and penetrate the layer of the soil above them with greater ease. Zasiadnikov (212) describes an apparatus to prepare such clay balls.

Though it has also been recommended (10, 51, 110, 212) to start new plantations by means of root cuttings, the results of experiments on the vegetative propagation of kok-saghyz obtained by different workers do not agree. Some (109, 133, 220) were successful, others (141) had considerable difficulty. A promoting effect of various growth substances on the percentage of cuttings rooted has been reported (119).

Extensive use of fertilizers, even on peat soils (56), has been recommended by all authors, and it has been suggested that fertilizers be given on at least three different occasions (198): first, organic and mineral fertilizers introduced during the deep plowing of the soil; second, mineral fertilizers introduced either before or simultaneously with sowing of the seeds; third, several introductions of various mineral fertilizers during the growing season itself. The last type of fertilizers is often introduced dissolved in water. The beneficial effects of introducing inorganic fertilizers during the growing season have been described by several workers (81, 140).

First-year plantations are dug late in the fall before the period of rains. During the first year of their growth, Altukhov (9) observed a continuous increase in the total fresh weight of roots and in the percentage of their rubber until the end of the growing season. From such observations he recommended digging such roots late in the season. According to him, the amount of rubber added during the second year of growth does not warrant leaving a well developed one-year plantation for the second year.

In the earlier years of kok-saghyz cultivation, when there was

a great shortage of seeds, they were collected even from one-year old plantations. In later years, when there was a fair supply, there has been a tendency not to collect seeds from one-year old plantations at all but to use the latter only as a source of rubber. Seeds have been collected recently only from plantations left for the second year. This change is due to the fact that seed collection is the most labor-consuming single operation in the enterprise, the cost of which may amount to 50% of the total cost (162). In the meantime, while the average seed production from one hectare of a one-year old plantation is three to five kilograms, a two-year old plantation yields 30 to 40 kg. per hectare (136). The greatest yield of seeds from a two-year old plantation has been reported as 215 kg. per hectare (136).

The yield of fresh roots per hectare of a one-year old plantation varied from zero to the highest value of 112 centners (one centner = 100 kg.) on a drained bog in White Russia (5). It is interesting to note that the Soviet Government (67) gives bonuses to the growers of kok-saghyz when their yields of fresh roots per hectare of one-year old plantations exceed 10 to 13.5 centners, depending on the region of cultivation. The date for digging roots from a one-year old plantation varies from the end of September until the middle of October, depending on the year and the locality.

On a kok-saghyz plantation in the second year of its life, flowering begins about June 1 and lasts until the middle of July, the exact dates varying from one geographical location to another. Each plant usually produces 30 to 40 flower heads within 10 to 15 days. A flower head is picked when it becomes cylindrical; it acquires a yellowish color then and the white pappus hairs become visible (1, 10, 197). Collected flower heads are dried and the pappus hairs removed from the seeds.

It is recommended to dig two-year old plantations after the peak of flowering and before the roots have shed their "gloves" (1, 11, 73, 197). In order to determine the best time for this in various regions of U.S.S.R., it was decided to carry out extensive tests in the summer of 1943. Operators of various commercial plantations were requested to take samples early in the spring, at the peak of seed formation, after the end of seed formation when the plants began to enter their period of rest, and again after the plants had

entered their rest period. A special pamphlet (18) gave instructions as to how to take samples and either to analyze them for their rubber content locally or to send them to a properly qualified laboratory.

Roots are lifted from the soil usually by a modified sugar-beet lifter or an ordinary plow, and are removed by hand. Their leaves are cut off and the roots sent to the factory either fresh or air-dried. Roots dug in the summer are usually sent in air-dried. Those dug in the fall are usually sent fresh. While waiting to be processed they may be stored in pits, though their conversion into a silage (204) has been suggested.

One of the greatest handicaps in the cultivation of kok-saghyz is its demand for a great deal of labor, and so mechanization of its cultivation is one of the first tasks to be solved (65, 190). While equipment suggested for tau-saghyz (155, 156, 189) can also be used for kok-saghyz, such machines are not very satisfactory. Suggestions on the type of a seed drill to be used for kok-saghyz have been made by several authors (1, 47, 179, 197). Filippov (53) described briefly a machine to collect seeds, and a detailed description of this machine is given elsewhere (1). An ordinary plow and a sugar-beet lifter have been used to dig the roots, but a special machine for the purpose has been suggested (17).

PATHOLOGY

A general description of the various parasites found on roots, leaves and seeds of kok-saghyz are given in various instruction booklets on how to grow the plants (1, 10, 197). There is one list of parasitic insects (59) and another describing those found on seeds and flower heads (63). Ghilarov (58) came to the conclusion that *Olibrus bicolor* F. and *Ceuthorrhynchus punctiger* Gyll are the two most important seed parasites. Since these two insects come to kok-saghyz from the common dandelion, he suggested extermination of the latter in the vicinity of the former, as one of the most important methods of control. In a more recent paper (62) this author also suggested dusting flower heads with naphthalene. An infestation by a parasite coming from *Brassica Napus* has also been reported (217).

According to Ghilarov (57), considerable destruction of various root rubber-bearing plants may be caused by root aphids and ants.

Skabrilovich (195, 196) described nematodes on kok-saghyz roots and reported (195) that in one case he observed infection up to 33% of all the roots examined. Root-rot on 15% of the plants examined was also reported (187). Emelianova (44) recommended chloropicrin (nitrochloroform) as a sterilizing agent to control various soil parasites. Two different species of *Orobanche* have been reported on kok-saghyz (61).

That kok-saghyz seeds may be infected with a number of fungi which later may seriously injure or even kill the developing seedlings, has been noted (86), and to control such fungi, treatments with arsenic (87) and copper (202) have been suggested. Rischkov (177) described a virus disease.

SELECTION

Having observed considerable polymorphism of kok-saghyz plants growing in different localities, Lipschitz (109) suggested that it may be due either to environment or to the existence of several genetically different forms. To test this point, Bulgakov (36) grew plants under identical conditions, using seeds from mesophytic, hygrophytic and xerophytic forms collected from different natural habitats. Since no significant differences were observed among the plants studied, this worker concluded that polymorphism is caused by environment. When seeds collected from the wild were sown side by side with those from cultivated plantations, their germination was less uniform and the roots produced were considerably smaller (64).

Kupzow (99) recommended using on kok-saghyz mainly the mass selection method, since in the early stages of selections such a method gives quicker results than the slower one of individual selection. Mass selection of large roots and their subsequent use to start new plantations for production of seeds is the standard procedure recommended by numerous authors (1, 10, 197). Since Kupzow observed plants with large roots to have pinnately lobed and divided leaves, he suggested selecting such plants and not those with simple leaves (99, 100, 102). According to this worker (102), the presence of specimens with different forms of leaves in the same plantation of one-year old plants indicates the existence of at least two genotypically different races. Some plants go through their ontogeny quickly and soon enter their later stages characterized by

pinnately lobed leaves. Such plants also flower usually the first year (101). Others go through their ontogeny slowly, they develop pinnately lobed leaves only under very favourable conditions and flower usually the second year. Work by several authors (50, 104, 134) has cast doubt on the value of using morphological characteristics of leaves as a yardstick in the selection of kok-saghyz.

It was also reported that only plants with medium size roots flower the first year, while those with the largest roots flower only the second year. On the strength of this observation several authors (88, 95, 99) have suggested that selection be made for plants which do not flower the first year.

Kok-saghyz can be hybridized only with other diploid and not with polyploid species of *Taraxacum* (159). Since such hybrids, even when established, are nearly completely sterile and are characterized by a lower rubber content, "distant hybridization is hardly advisable in breeding *T. kok-saghyz*" (159). Similar conclusions were also reached by others (93). It was stated (160) that the average setting of fruits in hybrids between kok-saghyz and other diploid dandelions amounted to only 2% to 3%.

Tetraploid kok-saghyz plants were produced by immersing into a solution of colchicine either seeds (218) or young seedlings (143). Reproducing tetraploid plants so formed by means of root cuttings, it was possible to propagate them further by seeds (144). Tetraploid kok-saghyz plants are reported to be of larger size, in general, with increased diameter of latex tubes in their roots and twice the weight of seeds as compared with those from diploid plants (144).

Koroleva (95) recommended that kok-saghyz plants be selected on the basis of root weight, percentage of rubber, and the weight of seeds. Among indirect desirable characteristics, this worker lists absence of flowering the first year and divided leaves. According to her, selection and favorable agricultural practices are the two most powerful factors in changing kok-saghyz from a wild into a cultivated plant. Discussing ways and means of changing it into a cultivated plant, Minbaev (136) also stresses the importance of favorable conditions during growth and recommends reducing the number of plants per hectare to not more than 300,000 or 400,000.

In discussing selection of kok-saghyz, Filippov (52) brings forth data to indicate that the most desirable form is not a single but a branched root. According to him, such a form contains a higher

percentage of rubber. He also describes roots with modified anatomical structure containing several additional cambial rings, and believes, along with others (165, 227), that the future cultivated forms of kok-saghyz should have such a modified anatomical structure with additional cambial rings.

According to Rudenskaia (182), from the anatomical point of view a large single root with latex tubes of large diameter is the most desirable. Her opinion is based on the observation that the larger a root is, the greater is the number of its latex tubes. On the other hand, the percentage of rubber in a root is correlated with the mean area of its latex tubes.

Minbaev (139) has suggested a new method of kok-saghyz breeding from the following considerations given in his earlier paper (137). The flowering period in both one- and two-year old plants is extended for several weeks, and this means that early flowers are produced under different external and internal conditions than the late ones. This is equally true for the florets in various circles of the same head, since they do not open all at once but within one or even several days. On the strength of this observation he suggested that the kind of gametes produced by a plant will vary, depending on the time of day or season when they are produced. He gives data to indicate that seeds collected in September produced plants with higher rubber content than those collected in August; also, that seeds collected from different circles of the same head had different characteristics which varied in a regular manner.

In spite of all work done on kok-saghyz so far, this plant is still represented essentially by its wild forms. There are only two references in the literature to improved forms. In one (216) a brief mention is made of two varieties with 15.5% and 16.5% of rubber, respectively. In the other (219) are described two varieties differing one from another in a number of characteristics.

TECHNOLOGY

Since rubber in a kok-saghyz root may be present either as latex or as coagulated threads (25), attempts have been made to extract both of these forms separately. In his first paper on this subject, Ignat'ev (68) described a method of extraction by which he was able to obtain up to 40% of the total rubber in the roots.

Low concentration of rubber in the latex and its instability on standing were the two main difficulties experienced by this author. In his later paper (69) he described several improvements of his original method and suggested a number of problems which should be studied. Siniavskii (191), giving the principle of latex extraction from kok-saghyz, suggested that even up to 50% of the rubber in the roots might be removed as latex. Cutting of kok-saghyz roots into small pieces is one of the first stages in the extraction, and Vasil'ev (208) investigated this stage from the mechanical point of view.

Ignat'ev, Uzina, and Erofeev (72) studied the effects of conditions during storage of kok-saghyz roots upon subsequent extraction of latex from them. They report that one-year old roots could be stored and used as a source of latex for six months during the winter, though the temperature of – 12° C. brought about coagulation of the latex in the roots within a few days.

The total rubber in the roots of kok-saghyz or the residual amount left after extraction of latex, can be obtained in several ways. Bobkov (29) suggested that cut roots be digested with sodium hydroxide in order to break the cells and to liberate the coagulated threads of rubber. Since the specific gravity of the particles of rubber is somewhat lower than that of other suspended parts, they can be separated from such a mixture by means of a centrifuge. Using this method, about 75% of the total rubber in roots is extracted and 25% lost. In order to cut down these losses, Bobkov (30) suggested the use of a number of special traps and reported that with the help of these the total extraction can be raised from 75% to 85% or 90%.

Tverskaia and Iossa (207) pointed out a number of disadvantages of the method suggested by Bobkov. They say it is complicated, expensive, dangerous on account of the use of a centrifuge, leaves a considerable percentage of rubber unextracted and, finally, affects the quality of the rubber extracted because of the alkali involved. For all these reasons they suggested the use of a mechanical method.

Kogan (90) objected to the construction of factories for extracting rubber by the mechanical method as suggested by Tverskaia and Iossa. He based his objections partly on the ground that this method is less familiar in Russia than the one described by Bobkov.

His main objections are, however, that the mechanical method precludes the utilization of inulin present in the roots for the production of alcohol, and he also claims that a centrifuge properly designed is a more efficient equipment than a ball mill.

Break-down of the root tissues for liberation of the rubber by means of micro-organisms has also been suggested by several authors (*29, 90, 207*). Though this method is quite simple, it requires large containers for the digestion, precludes utilization of inulin, and imparts a strong unpleasant odor to the final product. While extraction of rubber by means of solvents has been investigated for at least one of the saghyzes (176), no data have been found in the literature to recommend its use for kok-saghyz.

Fabritsiev and Vishnevskaia (45) extracted rubber from one-year old roots and studied its chemical and physical charasteristics. They reported that the initial relative viscosity of the non-plasticized pale crepe is two and a half times as high as that of rubber from kok-saghyz. After plastication for 21 minutes the relative viscosity for the pale crepe dropped to one-fifth of its original value, while that for kok-saghyz was slightly less than a third of its original value. The data obtained for the capillary rise of the rubber extracts in benzol were in agreement with those for the viscosity.

The technological characteristics of rubber from kok-saghyz were described and compared with those of imported natural rubber by Fabritsiev and Vishnevskaia (46). They studied the behaviour of kok-saghyz rubber alone and in mixtures with lamp black, coaolin, chalk and various softeners.

Ignat'ev and Ustimova (71) removed resins from crude kok-saghyz rubber, prepared a solution of pure rubber hydrocarbon isolated also from kok-saghyz, and studied the effects of adding various amounts of resins to a solution of such pure rubber. The viscosity of the rubber solution has been taken as an indicator of such effects. They reported that addition of resins lowers the viscosity of the gel but not of the sol solutions. For this reason they suggested that the molecular weight of rubber in a sol solution could be calculated according to the formula of Staudinger, whether resins are or are not present.

From their studies on the swelling of kok-saghyz rubber in various solvents, Ignat'ev and Senatorskaia (70) have concluded that the higher the degree of polymerization of rubber, the greater is its

swelling in a solvent. From the observation that a plasticized rubber has a lower capacity to swell, they suggested that plastication of rubber decreases the degree of its polymerization. In evaluating all the data on the physical characteristics of rubber from kok-saghyz, one should keep in mind the observation (121, 123) that such characteristics are not constant but vary, depending on the ontogenetic stage of a plant from which such rubber has been extracted.

Only fragmentary information is available on the actual utilization of rubber from kok-saghyz for manufacturing various articles. Thus Rogov and Magidov (178) reported that tires and inner tubes made from it differed but little, according to their mechanical characteristics, from those made from imported natural rubber. According to Shelepina (188), rubber from kok-saghyz could be substituted for smoked sheet in the production of glue, and the same is true in the production of rubber threads (206).

While rubber is the main product for which kok-saghyz was originally introduced into cultivation, its reported inulin content of up to 40% of the dry weight of roots makes this plant also desirable for the alcohol industry (27, 97). Thus a number of authors have suggested (28, 72, 90) that previous to the extraction of rubber inulin and sugars be removed from the roots and fermented into alcohol. It was reported that a ton of fresh roots should yield 60 to 65 liters of alcohol (29, 72), or for one ton of rubber extracted one should get about two tons of alcohol (90). Bobkov (28) suggested that in order to hydrolyze inulin present in kok-saghyz roots an acidity of at least pH–2.5 should be arranged. In his experiments on the fermentation of the roots, about 90% of the soluble carbohydrates present initially in the roots were fermented.

SUMMARY

Kok-saghyz is reported to be one of the most promising rubber plants which have been found within the last few years. It was discovered in 1931 in the central Asiatic regions of U.S.S.R., close to the Chinese border. Being in cultivation only for the last 12 years it is still fairly close to its original wild type, and its improved forms are just beginning to appear. This fact, together with its great demands for labor and the absence of specially designed machinery, represent the greatest difficulties in its present

day cultivation. Kok-saghyz, however, is a plant which seems to have considerable biological potentialities, and it responds greatly to the improved conditions of cultivation.

Kok-saghyz contains rubber in its roots, and the recent tendency in its cultivation is to grow it either as an annual or a biennial, depending whether one wishes mainly its roots or seeds. As a source of rubber, kok-saghyz is sown usually in the spring, and its roots are dug up late in the fall of the same year. As a source primarily of seeds, a plantation is left for the second year. Seeds are collected by the middle of the second season of growth, and roots are dug up shortly after the peak of seed production has been reached. Extraction of rubber from kok-saghyz roots does not present any serious difficulties.

Since kok-saghyz roots contain up to 27.89% of their weight as rubber, the main interest in this plant so far has been as a source of rubber. It should be remembered, however, that up to 40% of its dry roots is in the form of an easily hydrolyzable polysaccharide which can be fermented, and for this reason kok-saghyz may serve also as a raw material for the alcohol industry.

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SUPPLEMENT

The following changes in the foregoing account have been necessitated by literature which could not be included in the original writing.

Page 420. Delete last line and its continuation, and substitute:

Sexual reproduction is normal (158), with cross-pollination as the usual method. In native habitat of kok-saghyz, pollination has been reported (226) as carried out mainly by the burrowing bee (*Halictus*), while under the condtions of cultivation it is effected by

the ordinary honey bee (*Apis*). Occasional cases of self-pollination have also been reported.

Page 424, second paragraph. Add:

Under some conditions the individual vascular bundles of such a modified root may separate, and by the end of the growing season the whole root becomes transformed into a cluster of smaller rootlets (225).

Page 424, third paragraph. After "cambium (181)" insert:

Differentiation of the latex tubes in each circle is stimulated by the presence of young leaves, which are growing under favourable light conditions (230).

Page 424, fourth paragraph. After "circles (19, 181, 186)" insert:

According to Nichiporovich and Ivanitzkaja (229) the number of such circles in a root is closely connected with the number of leaves.

Page 430, second paragraph. Delete last two sentences and substitute:

In his earlier paper (122) Mashtakov reported synthesis of rubber in kok-saghyz roots during their rest period. The same author showed later (228) that such an increase is only relative, being due to the increase in the dry weight of roots. The absolute amounts of rubber remain the same. Neuman and Dobrovol'skaja (146) observed an increase in the rubber content of kok-saghyz roots during storage. Such an increase was promoted by the conditions of impeded gas exchange (223, 234). It was also stimulated by wilting, and checked when roots were kept at constant humidity (223).

Page 441. Delete fourth paragraph and substitute:

Tetraploid kok-saghyz plants were produced by immersing into a solution of colchicine either seeds (218, 235) or young seedlings (143, 222). Such plants are usually of larger size, with the increased diameter of their latex tubes (144) and higher amounts of rubber per root (235).

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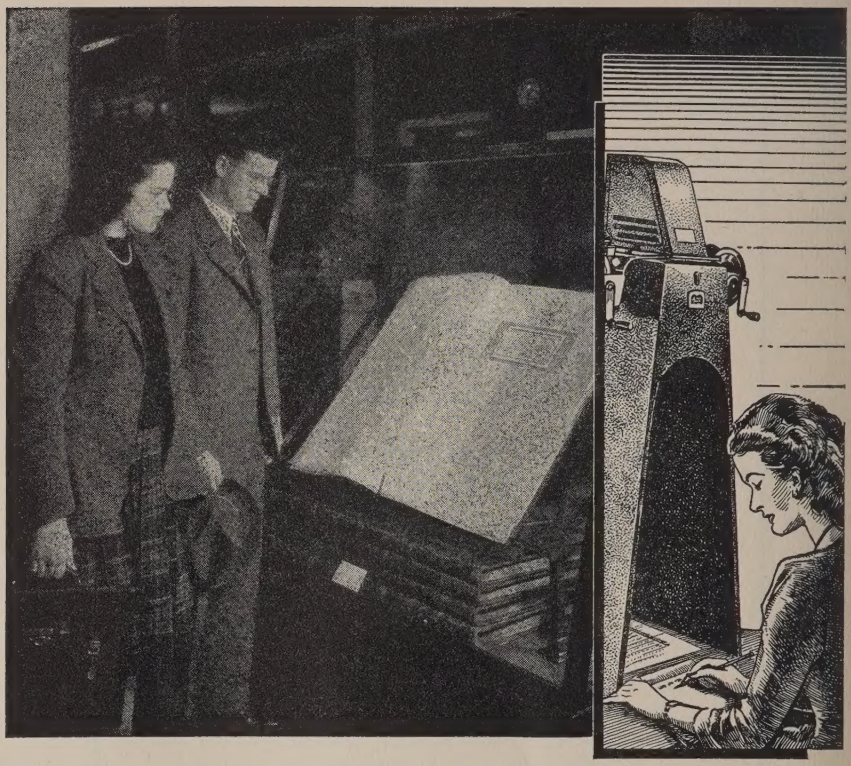

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